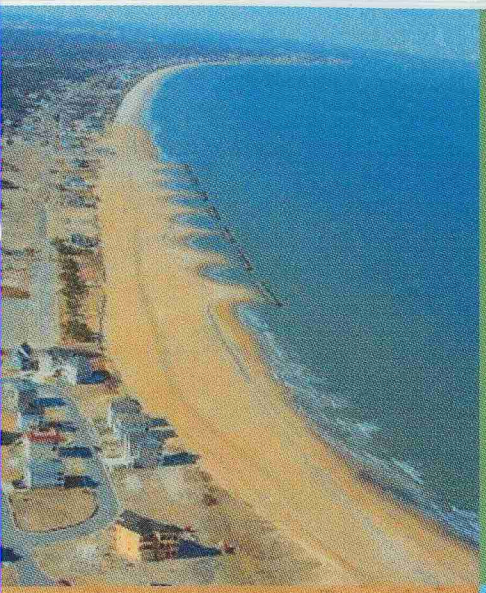

City of Norfolk

July 2006

Ocean View Beach

Sand Borrow Investigation, Permit *and* Design

MOFFATT & NICHOL

Executive Summary

The City of Norfolk, Virginia is seeking potential borrow areas for future beach nourishment projects along its Ocean View shoreline. Recent beach nourishment projects along Ocean View have taken sand from the eastern end of Thimble Shoal Channel (where the sediments are of sufficient beach quality). However, within the limits of the Federal navigation channel, Thimble Shoal Channel is now exhausted of its beach sand. Based on the findings of a January 2006 study conducted by Moffatt & Nichol, with input from the City and regulatory agencies, it was recommended to pursue investigation of the area offshore of the Ocean View shoreline (Willoughby and Crumps Bank) and outside the current Federal limits of Thimble Shoal Channel as potential borrow sources for future beach nourishment projects.

Vibracores and sediment samples were collected from areas of Willoughby and Crumps Bank and north of Thimble Shoal Channel to perform a sediment compatibility analysis and determine the usefulness of each area for beach nourishment borrow sources. Results indicate that a 550-acre area north of and within Thimble Shoal Channel, and a 460-acre area within Willoughby Bank contain beach quality sands. Available dredging volumes based on depths of beach quality sediment and maximum dredging depths were determined to be 12.1 million cubic yards for the Thimble Shoal Channel borrow area and 13.1 million cubic yards for the Willoughby Bank borrow area.

In order to provide the City with optimal flexibility and long-term volume needs, a Joint Permit Application (JPA) was prepared using both Thimble Shoal Channel and Willoughby Bank as borrow sources for future beach nourishment projects. The JPA includes dredging at the proposed borrow areas, beach nourishment covering approximately 7.2 miles of shoreline at Ocean View, and extension of 12 existing stormwater outfalls along Ocean View. The intent of the proposed beach nourishment is to abate a chronic shoreline erosion problem, increase protection to public and private property, provide storm protection, and restore the public beach. As noted in the JPA, it is envisioned that the City will complete individual smaller beach nourishment projects over time, as needed. The permit, as requested, would be valid for a six-year time period from 2006 to 2012.

For permitting purposes, a beach fill template including a sufficient dune and berm for storm protection was developed. The beach fill template was developed with consideration of previous dune and berm alignments designed for the East Ocean View and Willoughby Spit to Central Ocean View nourishment projects and to maximize storm protection, particularly in historically eroding areas. The total required beach fill volume was determined to be 2.37 million cubic yards with an overall average unit volume of 54 cubic yards per foot of shoreline. Stormwater outfall extensions ranging from 90 feet to 252 feet were also included in the JPA to allow for adequate pipe clearance with the proposed beach fill template.

A budget level opinion of probable cost was performed to evaluate beach nourishment dredging costs for using Thimble Shoal Channel, Willoughby Bank and Horseshoe Shoals, using both hopper dredge and hydraulic cutter-head pipeline dredge. Some cost

savings can be realized by using a contractor who may already be doing maintenance dredging for the Corps of Engineers in the adjacent Thimble Shoals navigation channel. Willoughby Bank offers the benefit that the material can be dredged with the cutter-head pipeline dredge which would be more economical for beach projects closer to the west end of Ocean View where the required pipeline lengths are shorter. Time of year restrictions may be an issue at both sites, due to migrating sea turtles and migrating/spawning of blue crabs. Some additional costs for clam mitigation and screening for the presence of unexploded ordinance may be an issue at Willoughby Bank.

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Appendices

1 Background & Objective

The City of Norfolk, Virginia is seeking potential borrow areas for future beach nourishment projects along its Ocean View shoreline. Recent beach nourishment projects along Ocean View have taken sand from the eastern end of Thimble Shoal Channel (where sediments are of a sufficient beach quality). However, within the limits of the Federal navigation channel, Thimble Shoal Channel is now exhausted of its beach sand. Based on the findings of a January 2006 study conducted by Moffatt & Nichol, with input from the City and regulatory agencies, it was recommended to pursue investigation of the area offshore of the Ocean View shoreline (Willoughby and Crumps Bank) and outside the current Federal limits of Thimble Shoal Channel as potential borrow sources for future beach nourishment projects. The purpose of this study is to better define preferred borrow areas by obtaining vibracores in Willoughby and Crumps Bank and Thimble Shoal Channel, performing a sediment compatibility analysis for each of the potential areas, defining a beach nourishment project along Ocean View and preparing a permit for dredging and beach nourishment.

In May of 2006, Alpine Ocean Seismic Survey, Inc. collected 40 vibracores in Willoughby and Crumps Bank and adjacent to the Thimble Shoal Channel. These vibracores were then sent to Professional Service Industries, Inc. for standard grain size analysis.

Gradation information was available for the native beach sediments from a study completed in 2004. In 2004, as part of a comprehensive survey and sampling program for the Norfolk shoreline, native beach sediment samples were collected by Waterway Survey and Engineering along 39 transects, numbered from west to east and spaced at approximately 1000 ft across the Ocean View shoreline.

Using the results from these two studies the best potential borrow areas in terms of proximity to Ocean View, potential volume of material available, and compatibility of material with native sands along Ocean View were determined. Using these results, suitable borrow areas were delineated, a dune and beach design was determined, and a Joint Permit Application (JPA) was prepared. The JPA seeks to allow the City permission to dredge the specified areas (**Figure 1**) and nourish the Ocean View shoreline. The goal of the permit is to allow maximum flexibility to the City for future beach nourishment and dune restoration projects.

This report details the collected sediment data, methods used to evaluate the suitability of these sediment sources for beach nourishment along Ocean View, and recommendations for specific borrow areas in Willoughby and Crumps Bank and adjacent to Thimble Shoal Channel.

2 Field Data Collection & Analysis

Based on previous studies and conversations with regulatory agencies, a vibracore sampling plan was developed to better define the areas of suitable borrow sources for future beach nourishment projects. In May of 2006, Alpine Ocean Seismic Survey, Inc. used an Alpine model 270 pneumatic Vibracore to collect 40 vibracores in an area adjacent to Thimble Shoal Channel and along Willoughby and Crumps Bank. The locations of the collected vibracores are shown on **Figure 2** and **Figure 3** for the two areas, respectively. The vibracores ranged from 10 to 20 feet in length. Actual locations were determined using the vessel's DGPS navigation system

(accuracy of better than 3m +/-), interfaced to Hypack Max software. The Alpine Vibracore is equipped with a system to measure and continuously record the rate and depth of penetration for each core. The result is a graph of the rate of penetration for each core. Water depth, date and time of each core, and total penetration and recovery for each core was also recorded. Depths were corrected to elevations based on NOAA's tide station at the Chesapeake Bay Bridge Tunnel. Detailed vibracore logs are presented in **Appendix A**.

Cores were split on the barge and logged by a geologist. Approximately 6 representative samples from each of the 40 vibracores were placed in bags and labeled with core number and depth. Individual bag samples (147) from the vibracores were sent to Professional Service Industries, Inc. (PSI) for standard grain size analysis. Most of the samples that were not tested included clays and silts that were easily determined in the field to be poor material for beach fill. The gradation analyses performed by PSI included representative samples from each vibracore at varying depths. Sediment analyses followed ASTM standards (ASTM D2487) and included the following sieve sizes: #4, #10, #16, #30, #50, #60, #80, #100, #140, and #200. Results of the grain size analysis are described in a report from Professional Service Industries, Inc included as **Appendix B**. The vibracores were then compared to native beach samples previously obtained from Willoughby Spit to East Ocean View to determine sediment compatibility.

In addition to the new vibracores, **Appendices C and D** contain historic vibracores from within the Willoughby Bank and Thimble Shoal Channel borrow areas.

3 Sediment Compatibility

As part of the grain size analysis performed by PSI, the median grain size diameter (D_{50}) for each sample was determined (where possible) as well as the percentage of fines (percent passing the #200 sieve). The D_{50} and percent fines for each sample are presented on **Table 1** along with the approximate ground elevation for each vibracore. Where the D_{50} is shown as "undetermined", more than 50 percent of the sample passed through the #200 sieve and the median grain size could not be determined (denoting a material too fine to be used as beach fill). The USACE Coastal Engineering Manual (CEM) recommends that, in general, the presence of very fine sand, silt and clay be limited to less than 10 percent for material to be used as beach fill. If borrow material with higher fines content is used, an increased amount of material must be handled to obtain the usable portion, increasing costs.

Based on field observations and initial examination of vibracore grain size analysis data, it was determined that two potential borrow areas exist containing material that may be suitable for beach placement. The first area is located north of Thimble Shoal Channel east of the Chesapeake Bay Bridge Tunnel and is approximately 550 acres. **Figure 4** shows this area with both recent and historical vibracore samples collected within the borrow area. Vibracore logs for those historical vibracores located within the Thimble Shoal borrow area are included in **Appendix C**.

The second area is located on Willoughby Bank and south of Thimble Shoal Channel, approximately 5,000 ft east of the Hampton-Roads Bridge Tunnel. This area is approximately 460 acres. **Figure 5** shows this area with both recent and historical vibracore samples collected

within the borrow area. Vibracore logs for those historical vibracores located within the Willoughby Bank borrow area are included in **Appendix D**.

Based on examination of the vibracore grain size analysis data as well as field observations, it was determined that the vibracores taken within Crumps Bank and the eastern portion of Willoughby Bank contain primarily silts and silty clays. These include vibracores 06OV-08 through 06OV-24, 06OV-29, and 06OV-38 through 06OV-39, which generally have fines contents upwards of 20%, as shown on **Table 1**. The vibracores taken at 06OV-26 and 06OV-34 have reasonable percent fines contents and D_{50} values in the range of the native beach sediments. However, these vibracores are surrounded by poor sediments and are isolated from the other beach quality sediments, making them uneconomical choices for potential borrow sources. Therefore, this area was determined unsuitable as a potential borrow source for beach quality sediment.

The suitability of material in each of the potential borrow areas was further analyzed by comparison of the material to native beach sediment along Willoughby Spit to East Ocean View, as discussed in the following sections.

Table 1. Median Grain Size and Percent Fines for Vibracores at Willoughby and Crumps Bank, Thimble Shoal Channel

Sample (@ Feet Below Ground)	Ground Elevation (MLLW)	D_{50} (mm)	Percent Fines (Passing #200 sieve)
06OV-01 @ 0-0.5 FT	-32.1 ft	0.107	10.8
06OV-01 @ 2-2.5 FT		0.117	8.9
06OV-01 @ 5-5.5 FT		0.170	4.4
06OV-01 @ 10-10.5 FT		0.388	5.0
06OV-01 @ 16 FT		0.412	6.4
06OV-02 @ 0-0.5 FT	-36.6 ft	0.293	9.6
06OV-02 @ 2-2.5 FT		0.155	9.9
06OV-02 @ 5-5.5 FT		0.110	8.3
06OV-02 @ 10-10.5 FT		0.183	13.6
06OV-02 @ 12 FT		0.442	5.7
06OV-02 @ 16.9 FT		0.201	4.8
06OV-03 @ 0-0.5 FT	-36.6 ft	0.117	10.8
06OV-03 @ 2-2.5 FT		0.107	13.3
06OV-03 @ 5-5.5 FT		0.115	10.4
06OV-03 @ 10-10.5 FT		0.100	18.8
06OV-03 @ 15 FT		0.224	4.5
06OV-03 @ 18 FT		0.112	22.4
06OV-04 @ 0-0.5 FT	-42.6 ft	0.259	10.3
06OV-04 @ 2-2.5 FT		0.400	2.5
06OV-04 @ 5-5.5 FT		0.393	3.3
06OV-04 @ 10-10.5 FT		0.217	2.2
06OV-04 @ 15 FT		0.478	1.8
06OV-04 @ 19.5 FT		Undetermined	65.2
06OV-05 @ 0-0.5 FT	-42 ft	0.307	2.1
06OV-05 @ 2-2.5 FT		0.274	10.5
06OV-05 @ 5-5.5 FT		0.211	15.8
06OV-05 @ 10-10.5 FT		0.327	1.4
06OV-05 @ 15 FT		0.494	3.2
06OV-05 @ 17.5 FT		0.260	4.9
06OV-06 @ 0-0.5 FT	-48.4 ft	0.322	4.4
06OV-06 @ 2-2.5 FT		0.335	1.7
06OV-06 @ 5-5.5 FT		0.255	2.3
06OV-06 @ 10-10.5 FT		0.503	1.5
06OV-06 @ 15 FT		0.887	1.2
06OV-06 @ 19 FT		0.427	1.2
06OV-07 @ 0-0.5 FT	-23.7 ft	0.363	5.7
06OV-07 @ 2-4 FT		0.342	4.1
06OV-07 @ 4-5 FT		0.151	18.6
06OV-07 @ 7-8 FT		0.546	7.3
06OV-07 @ 13 FT		0.386	2.0
06OV-08 @ 0-1 FT	-17.2 ft	0.251	27.0
06OV-08 @ 3-4 FT		Undetermined	85.9
06OV-09 @ 0-1 FT	-20.8 ft	0.573	19.5
06OV-09 @ 5 FT		Undetermined	59.2
06OV-10 @ 0-1 FT	-21.3 ft	0.124	17.0
06OV-10 @ 1-2 FT		0.085	35.4
06OV-10 @ 4-5 FT		0.077	47.1
06OV-10 @ 8-8.5 FT		0.180	27.7
06OV-10 @ 9.5-10 FT		0.186	22.4

Table 1. Median Grain Size and Percent Fines for Vibracores at Willoughby and Crumps Bank, Thimble Shoal Channel cont.

Sample (@ Feet Below Ground)	Ground Elevation (MLLW)	D_{50} (mm)	Percent Fines (Passing #200 sieve)
06OV-11 @ 1-1.5 FT	-21.8 ft	Undetermined	77.1
06OV-11 @ 3 FT		0.093	29.0
06OV-11 @ 5-6 FT		0.245	3.1
06OV-12 @ 0-0.5 FT	-18.4 ft	0.106	26.2
06OV-12 @ 5-5.5 FT		0.078	45.5
06OV-13 @ 0-0.5 FT	-24.2 ft	Undetermined	55.1
06OV-13 @ 2-2.5 FT		0.078	45.6
06OV-14 @ 0-0.5 FT	-23.5 ft	0.106	25.9
06OV-14 @ 5-5.5 FT		Undetermined	95.1
06OV-15 @ 0-0.5 FT	-24.2 ft	0.091	25.8
06OV-15 @ 2.5-3 FT		0.230	9.9
06OV-15 @ 5-5.5 FT		0.158	12.4
06OV-16 @ 0-0.5 FT	-18.3 ft	0.092	31.2
06OV-16 @ 2-2.5 FT		0.088	27.9
06OV-17 @ 0-0.5 FT	-25.4 ft	0.115	38.6
06OV-17 @ 2-2.5 FT		Undetermined	57.6
06OV-18 @ 2-2.5 FT	-21.9 ft	Undetermined	62.2
06OV-18 @ 10-10.5 FT		Undetermined	83.2
06OV-19 @ 0-0.5 FT	-25.1 ft	0.093	25.9
06OV-19 @ 2-2.5 FT		0.085	34.4
06OV-20 @ 2-2.5 FT	-21.64 ft	Undetermined	85.7
06OV-21 @ 2-2.5 FT	-24.8 ft	Undetermined	94.1
06OV-22 @ 2-2.5 FT	-29.8 ft	Undetermined	75.3
06OV-23 @ 0-0.5 FT	-22.1 ft	0.082	39.4
06OV-23 @ 2-2.5 FT		Undetermined	72.2
06OV-24 @ 0-0.5 FT	-22.6 ft	0.093	21.0
06OV-24 @ 2-2.5 FT		0.095	17.1
06OV-25 @ 0-0.5 FT	-13.6 ft	Undetermined	93.9
06OV-25 @ 2-2.5 FT		0.577	12.8
06OV-25 @ 5-5.5 FT		0.717	4.5
06OV-25 @ 7 FT		0.510	10.7
06OV-25 @ 10-10.5 FT		0.819	1.3
06OV-25 @ 12 FT		0.588	0.9
06OV-25 @ 15 FT		0.620	0.6
06OV-25 @ 20 FT		0.495	8.7
06OV-26 @ 0-0.5 FT	-16.8 ft	0.276	1.9
06OV-26 @ 2-2.5 FT		0.343	7.6
06OV-26 @ 10-10.5 FT		0.249	14.3
06OV-27 @ 0-0.5 FT	-18.3 ft	0.510	1.3
06OV-27 @ 2-2.5 FT		0.453	1.7
06OV-27 @ 5-5.5 FT		0.376	1.3
06OV-27 @ 10-10.5 FT		0.304	6.7
06OV-27 @ 15 FT		0.385	1.4
06OV-27 @ 19 FT		0.433	1.0
06OV-28 @ 0-0.5 FT	-15.4 ft	0.468	1.2
06OV-28 @ 2-2.5 FT		0.485	0.6
06OV-28 @ 5-5.5 FT		0.132	28.9
06OV-28 @ 10-10.5 FT		0.275	5.0
06OV-28 @ 18 FT		0.236	23.7

Table 1. Median Grain Size and Percent Fines for Vibracores at Willoughby and Crumps Bank, Thimble Shoal Channel cont.

Sample (@ Feet Below Ground)	Ground Elevation (MLLW)	D_{50} (mm)	Percent Fines (Passing #200 sieve)
06OV-29 @ 0-0.5 FT	-16.8 ft	0.304	25.4
06OV-29 @ 5-5.5 FT		0.089	32.6
06OV-30 @ 0-0.5 FT	-19.7 ft	0.217	15.1
06OV-30 @ 2-2.5 FT		0.264	20.1
06OV-30 @ 10-10.5 FT		0.231	11.2
06OV-31 @ 0-0.5 FT	-8.44 ft	0.413	0.8
06OV-31 @ 2-2.5 FT		0.244	2.1
06OV-31 @ 5-5.5 FT		0.585	1.0
06OV-32 @ 0-0.5 FT	-21.5 ft	0.409	3.1
06OV-32 @ 2-2.5 FT		0.172	17.5
06OV-32 @ 5-5.5 FT		0.205	24.1
06OV-32 @ 10-10.5 FT		0.262	4.0
06OV-32 @ 16 FT		0.241	9.7
06OV-33 @ 0-0.5 FT	-14.05 ft	0.454	1.7
06OV-33 @ 2-2.5 FT		0.342	2.8
06OV-33 @ 5-5.5 FT		0.272	6.9
06OV-33 @ 10-10.5 FT		0.088	32.5
06OV-33 @ 16 FT		0.201	15.7
06OV-34 @ 0-0.5 FT	-9.3 ft	0.427	1.0
06OV-34 @ 2-2.5 FT		0.470	1.0
06OV-34 @ 5-5.5 FT		0.424	1.2
06OV-34 @ 10-10.5 FT		0.273	7.7
06OV-34 @ 15 FT		0.089	33.3
06OV-35 @ 0-0.5 FT	-15.6 ft	0.487	1.1
06OV-35 @ 2-2.5 FT		0.469	3.2
06OV-35 @ 5-5.5 FT		0.273	6.5
06OV-35 @ 10-10.5 FT		0.204	20.9
06OV-35 @ 13 FT		0.204	25.2
06OV-36 @ 0-0.5 FT	-23.3 ft	0.275	3.6
06OV-36 @ 2-2.5 FT		0.406	6.0
06OV-36 @ 5-5.5 FT		0.491	2.6
06OV-36 @ 10-10.5 FT		0.494	1.3
06OV-36 @ 15FT		0.478	0.5
06OV-37 @ 0-0.5 FT	-28.4 ft	0.373	2.8
06OV-37 @ 2-2.5 FT		0.350	2.5
06OV-37 @ 5-5.5 FT		0.241	15.7
06OV-37 @ 10-10.5 FT		0.213	33.9
06OV-38 @ 0-0.5 FT	-26 ft	0.247	18.1
06OV-38 @ 2-2.5 FT		0.216	27.8
06OV-38 @ 5-5.5 FT		0.248	16.1
06OV-38 @ 10-10.5 FT		0.214	35.1
06OV-39 @ 0-0.5 FT	-17 ft	0.093	46.3
06OV-39 @ 5-5.5 FT		0.176	15.2
06OV-40 @ 0-0.5 FT	-27.4 ft	0.324	2.0
06OV-40 @ 2-2.5 FT		0.329	7.0
06OV-40 @ 5-5.5 FT		0.206	35.4
06OV-40 @ 10-10.5 FT		0.218	39.3

3.1 Native Beach Sediment Characteristics

In 2004, as part of a comprehensive survey and sampling program for the Ocean View shoreline, sediment samples were collected by Waterway Survey and Engineering along 39 transects, numbered from west to east and spaced approximately 1000 feet apart, across the Ocean View shoreline (see **Figure 6**). Grab samples were collected at 1) top of dune, 2) toe of dune, 3) mid-beach (halfway between the dune toe and waterline), 4) high water line, 5) elevation -6 feet NAVD88, and 6) elevation -15 feet NAVD88 for all transects except those at East Ocean View (OV36 – OV 39). The East Ocean View samples were taken at mid-dune, mid-beach, and between the high and low water lines.

All samples were sent to Geotechnical Environmental Testing Solutions, Inc. for standard grain size analysis (following ASTM D2487 standards) using the following sieve sizes: #4, #10, #16, #30, #40, #50, #60, #80, #100, #140, and #200. Results of the grain size analysis were described in a report from Geotechnical Environmental Testing Solutions, Inc., dated September 15, 2004. These test results including the resulting grain size distributions are included in **Appendix E**.

3.1.1 Native Beach Grain Size Distributions

Based on methodologies presented in the U.S. Army Corps of Engineers (USACE) Coastal Engineering Manual (CEM), a composite native beach grain size distribution was computed from the available sediment data. Sediment data (grain size distributions) were averaged alongshore for all 39 sample locations at 1) dune toe, 2) mid beach, 3) high water line, and 4) -6 ft NAVD88 (where the proposed beach fill would be predominantly placed). Next, an overall average distribution was computed from the average dune toe, mid beach, high water line, and -6 ft distributions, yielding the composite grain size distribution for the entire project area. For the purpose of computing overall average distributions and statistics for the entire shoreline, samples taken at East Ocean View at mid-dune, mid-beach, and between the high and low water lines were averaged with samples taken elsewhere at the dune toe, mid-beach, and high water line, respectively. Additionally, it should be noted that there were no samples taken at -6 ft in the East Ocean View region. **Figure 7** shows the average distributions computed for the dune toe, mid beach, high water line and -6 ft NAVD88 samples, and the resulting composite distribution.

3.1.2 Native Beach Median Grain Size

Median grain size diameters were computed for each station and sample location and averaged along each transect (between the dune toe and -6 ft) and along the shoreline (**Table 2**). Average D_{50} values generally range from 0.4-0.6 mm from Willoughby Spit to Central Ocean View (OV1-OV22), indicating coarser sediment. From Central through East Ocean View, the D_{50} values typically range between 0.3-0.5 mm (OV22-OV39). Overall trends indicate coarser sediment along the subaerial portion of the profile. The overall average D_{50} for the Ocean View shoreline is 0.43 mm. This value is consistent with previous sediment analyses that utilized the same data to characterize portions of Ocean View, including Willoughby Spit to Central Ocean View (average D_{50} computed as 0.49 mm) and the East Ocean View area (average D_{50} computed as 0.41 mm).

Table 2. Native Beach Sediment Median Grain Sizes for Willoughby Spit to East Ocean View

Station	D_{50}-dune toe (mm)	D_{50}-mid beach (mm)	D_{50}-high water line (mm)	D_{50}--6ft (mm)	D_{50}-average of dune toe, mid beach, high water line, and -6 ft (mm)
OV1	0.68	0.56	0.89	NA	0.71
OV2	1.03	0.46	0.58	0.44	0.63
OV3	0.42	0.42	NA	0.23	0.36
OV4	0.43	0.50	0.33	0.28	0.39
OV5	0.36	0.36	0.37	0.33	0.35
OV6	0.47	0.49	0.62	0.22	0.45
OV7	0.42	0.53	0.62	0.27	0.46
OV8	0.42	0.34	0.78	0.21	0.44
OV9	0.47	0.76	0.82	0.26	0.58
OV10	0.54	0.42	0.54	0.23	0.43
OV11	0.50	0.52	0.50	NA	0.51
OV12	0.32	0.49	0.55	0.21	0.39
OV13	0.38	0.42	0.51	0.21	0.38
OV14	0.53	0.55	0.63	0.21	0.48
OV15	0.56	0.51	0.67	0.22	0.49
OV16	0.54	0.50	0.82	0.32	0.54
OV17	0.53	0.71	0.56	0.23	0.51
OV18	0.53	0.40	0.87	0.79	0.65
OV19	0.51	0.57	0.62	NA	0.56
OV20	0.53	0.55	0.56	0.26	0.48
OV21	0.50	0.83	0.52	0.23	0.52
OV22	0.49	0.33	0.58	0.43	0.46
OV23	0.28	0.51	0.49	0.26	0.39
OV24	0.26	0.38	0.48	0.30	0.36
OV25	0.32	0.32	0.45	NA	0.36
OV26	0.26	0.37	0.37	0.22	0.30
OV27	0.24	0.26	0.36	0.20	0.26
OV28	0.29	0.27	0.35	0.23	0.28
OV29	0.30	0.27	0.30	NA	0.29
OV30	0.28	0.27	0.41	NA	0.32
OV31	0.32	0.28	0.36	NA	0.32
OV32	0.28	0.30	0.41	NA	0.33
OV33	0.31	0.30	0.47	NA	0.36
OV34	0.28	0.29	0.51	0.24	0.33
OV35	0.38	0.32	0.25	NA	0.32
OV36	0.23	0.71	0.28	NA	0.41
OV37	0.42	0.35	0.41	NA	0.39
OV38	0.29	0.49	0.51	NA	0.43
OV39	0.31	0.52	0.63	NA	0.49
AVG	**0.41**	**0.45**	**0.52**	**0.28**	**0.43**
MIN	**0.23**	**0.26**	**0.25**	**0.20**	**0.26**
MAX	**1.03**	**0.83**	**0.87**	**0.79**	**0.71**

3.2 Suitability of Proposed Borrow Areas

To further examine the suitability of sediment for nourishment of the Ocean View shoreline, the native material characteristics were compared with those of the vibracore samples within the proposed Thimble Shoal Channel and Willoughby Bank borrow areas.

Along with examining the D_{50} values and percent fines, overfill factors were computed to compare the native material characteristics with those of the vibracore samples within the proposed borrow areas. The CEM defines the overfill factor (R_A) as "*the volume of borrow material required to produce a stable unit of usable fill material with the same grain size characteristics as the native beach sand.*" The closer the overfill ratio is to 1.0, the better the sand source. The methodology for computing the overfill factor was taken from the CEM and consisted of calculating relationships based on the phi-scale grain size distributions of the potential borrow site and the native beach. These relationships can then be plotted on a nomograph in the CEM to determine the overfill factor, R_A.

The relationships used in computing the overfill factors are the mean sediment diameter in phi-scale units (M_ϕ) and the standard deviation in phi-scale units (σ_ϕ), and are defined in the CEM as:

$$M_\varphi = \left(\frac{\varphi_{16} + \varphi_{50} + \varphi_{84}}{3} \right) \quad (1)$$

and

$$\sigma_\varphi = \left[\left(\frac{\varphi_{84} - \varphi_{16}}{4} \right) + \left(\frac{\varphi_{95} - \varphi_5}{6} \right) \right] \quad (2).$$

Characteristics of the native beach sand were determined from the composite grain size distribution (average of distributions between dune toe and -6 ft NAVD88 for the study area). While there is some variability in these distributions along the shoreline, an overall average was used since the borrow site, construction scheduling, and costs would not allow specialized dredging and placement programs. The required input for computing the overfill factors were determined from the phi-scale grain size distribution. The phi scale distribution for the native beach and the resulting characteristics used for computing the overfill factor for the native beach are shown on **Figure 8**. Characteristics of borrow area sediments were determined from the vibracore sample grain size distributions included in **Appendix B**.

The overfill factors were computed using ACES (Automated Coastal Engineering System) software, part of the CEDAS (Coastal Engineering Design and Analysis System) package distributed by Veri-Tech.

3.2.1 Summary of Thimble Shoal Channel Vibracore Analysis

Based on field observations and initial sediment comparisons, the vibracores collected from Thimble Shoal (vibracores 06OV-01 to 06OV-06) proved to be predominately beach quality

sand with some silty sand. Again, the six vibracores were located to represent an area of approximately 550 acres.

Overfill factors (R_A) were computed for the sample depths within the potential borrow area for borings 06OV-01 through 06OV-06, and are shown in **Table 3** along with other pertinent sediment characteristics for each sample. The resulting phi-scale means and standard deviations for the native beach and each vibracore sample were used in determining the overfill factors. "ND" indicates that the overfill factors were not determined due to a lack of data. This occurred generally where the percentage of fines was so high that Φ_{95}, Φ_{84}, or both could not be determined, and therefore, resulting means and standard deviations could not be calculated. However, as shown, most samples collected in the Thimble Shoal Channel borrow area had approximately 10% or less fines. In a few cases, the mean phi size and standard deviation were determined, but the solution for the overfill factor was undefined, indicating that the material would be unstable.

The D_{50} values and percent fines indicate that the sediment sampled from vibracores 06OV-04 - 06OV-06 (see **Figure 4**) is most compatible with the native beach material. In general, D_{50} values in this region range from 0.2 mm to 0.5 mm, with the exception of a coarse layer in 06OV-06 where the D_{50} value is 0.9 mm. The percent fines are generally less than 5%, with the exception of a few intermediate layers containing around 10% fines. Where determined, overfill factors determined for these vibracore samples are typically close to 1.0, with pockets of unsuitable material. Higher overfill factors (e.g. 06OV-05 @ 17.5 ft and 06OV-06 @ 5-5.5 ft) were calculated where the sediment distributions were finer overall. Sediment characteristics for vibracores 06OV-01 – 06OV-03 (see **Figure 4**) indicate that material in these areas are generally finer than the native beach material. While the percent fines are typically 10% or less, the D_{50} values are fairly low, ranging from 0.1 mm to 0.4 mm. Overfill factors were not determinable for most samples in this region.

Previous beach fill projects, including East Ocean View and Willoughby Spit to Central Ocean View have used material from Thimble Shoal Channel, just south of these samples. For both of these projects, losses of fines during placement occurred. Therefore, it may be expected that an additional percentage of fines would be lost during and after placement in future nourishment projects, thereby increasing the overfill ratio.

Additionally, **Table 3** shows the estimated top elevation of each sample relative to mean lower low water (MLLW). As shown, the Thimble Shoal Channel vibracores had ground surface elevations ranging from –32.1 feet to -48.4 feet MLLW. Based on the comparison of vibracore data and native beach sediment, suitable material was found up to depths approximately 16-19 feet below ground, particularly along the southern and western boundaries. The maximum allowable dredge depth within the channel is -55 feet-MLLW. This maximum allowable dredge depth was assumed to determine the available volume of material within the borrow area, as will be discussed in **Section 4**.

Table 3. Overfill Factors for Thimble Shoal Channel Borrow Area

Sample	Top Elevation of Sample (ft-MLLW)	D_{50} (mm)	Percent Fines (Passing #200 sieve)	Native Beach		Borrow Area		R_A
				$M_{\phi n}$	$\sigma_{\phi n}$	$M_{\phi b}$	$\sigma_{\phi b}$	
06OV-01 @ 0-0.5 FT	-32.1	0.107	10.8	1.36	0.89	3.25	ND	ND
06OV-01 @ 2-2.5 FT		0.117	8.9	1.36	0.89	3.14	ND	ND
06OV-01 @ 5-5.5 FT		0.170	4.4	1.36	0.89	2.55	0.79	ND
06OV-01 @ 10-10.5 FT		0.388	5.0	1.36	0.89	1.37	1.07	1.10
06OV-01 @ 16 FT		0.412	6.4	1.36	0.89	1.30	ND	ND
06OV-02 @ 0-0.5 FT	-36.6	0.293	9.6	1.36	0.89	1.93	ND	ND
06OV-02 @ 2-2.5 FT		0.155	9.9	1.36	0.89	2.59	ND	ND
06OV-02 @ 5-5.5 FT		0.110	8.3	1.36	0.89	3.22	ND	ND
06OV-02 @ 10-10.5 FT		0.183	13.6	1.36	0.89	2.54	ND	ND
06OV-02 @ 12 FT		0.442	5.7	1.36	0.89	0.87	ND	ND
06OV-02 @ 16.9 FT		0.201	4.8	1.36	0.89	2.31	0.59	ND
06OV-03 @ 0-0.5 FT	-36.6	0.117	10.8	1.36	0.89	3.17	ND	ND
06OV-03 @ 2-2.5 FT		0.107	13.3	1.36	0.89	3.26	ND	ND
06OV-03 @ 5-5.5 FT		0.115	10.4	1.36	0.89	3.19	ND	ND
06OV-03 @ 10-10.5 FT		0.100	18.8	1.36	0.89	ND	ND	ND
06OV-03 @ 15 FT		0.224	4.5	1.36	0.89	2.19	1.03	3.04
06OV-03 @ 18 FT		0.112	22.4	1.36	0.89	ND	ND	ND
06OV-04 @ 0-0.5 FT	-42.6	0.259	10.3	1.36	0.89	1.87	ND	ND
06OV-04 @ 2-2.5 FT		0.400	2.5	1.36	0.89	1.22	1.14	1.07
06OV-04 @ 5-5.5 FT		0.393	3.3	1.36	0.89	1.03	1.48	1.14
06OV-04 @ 10-10.5 FT		0.217	2.2	1.36	0.89	2.21	0.12	1.00
06OV-04 @ 15 FT		0.478	1.8	1.36	0.89	1.03	0.76	1.00
06OV-04 @ 19.5 FT		ND	65.2	1.36	0.89	0.91	ND	ND
06OV-05 @ 0-0.5 FT	-42	0.307	2.1	1.36	0.89	1.78	0.99	1.65
06OV-05 @ 2-2.5 FT		0.274	10.5	1.36	0.89	1.74	ND	ND
06OV-05 @ 5-5.5 FT		0.211	15.8	1.36	0.89	ND	ND	ND
06OV-05 @ 10-10.5 FT		0.327	1.4	1.36	0.89	1.53	0.65	1.89
06OV-05 @ 15 FT		0.494	3.2	1.36	0.89	0.97	0.78	1.00
06OV-05 @ 17.5 FT		0.260	4.9	1.36	0.89	1.88	0.71	4.36
06OV-06 @ 0-0.5 FT	-48.4	0.322	4.4	1.36	0.89	1.59	1.25	1.30
06OV-06 @ 2-2.5 FT		0.335	1.7	1.36	0.89	1.24	1.14	1.08
06OV-06 @ 5-5.5 FT		0.255	2.3	1.36	0.89	1.80	0.83	2.21
06OV-06 @ 10-10.5 FT		0.503	1.5	1.36	0.89	0.94	0.77	1.00
06OV-06 @ 15 FT		0.887	1.2	1.36	0.89	0.00	1.53	1.02
06OV-06 @ 19 FT		0.427	1.2	1.36	0.89	0.80	ND	ND

3.2.2 *Summary of Willoughby Bank Vibracore Analysis*

The vibracores collected within the Willoughby Bank borrow area (see **Figure 5**) proved to contain beach quality sands with low percentages of silts/clays and average D_{50} values in the range of the native beach sediment. This is an area of approximately 460 acres.

Overfill factors (R_A) were computed for the sample depths within the potential borrow area at Willoughby Bank. The results of this analysis are presented in **Table 4** along with other pertinent sediment characteristics. Again, "ND" indicates that the overfill factors were not determined due to a lack of data, resulting from fines contents exceeding 5%. As shown, most samples collected in the Willoughby Bank borrow area had approximately less than 10% fines, excluding pockets of silty material. In a few cases, the mean phi size and standard deviation were determined, but the solution for the overfill factor was undefined, indicating that the material would be unstable.

As shown on **Table 4**, D_{50} values of the vibracore samples range from 0.1 mm to 0.8 mm, with a majority of the D_{50} values in the range of 0.2 mm to 0.5 mm. As mentioned, percent fines are generally less than 10%, with pockets of silty material in the lower strata. Where determined, the overfill factors range from 1.0 to 8.25, however, many of the values are close to 1.0, indicating that the material is optimal in terms of sediment compatibility. Higher overfill factors (e.g. 06OV-27 @ 15 ft, 06OV-28 @ 10-10.5 ft, and 06OV-37 @ 2-2.5 ft) were calculated where the sediment distributions were finer overall and/or were poorly graded.

Additionally, **Table 4** shows the estimated top elevation of each sample relative to mean lower low water (MLLW). As shown, the Willoughby Bank vibracores had ground surface elevations ranging from -8.4 feet to -28.4 feet MLLW. Based on the comparison of vibracore data and native beach sediment, suitable material was found up to depths approximately 20 feet below ground, particularly along the southern and western boundaries. For the purposes of computing available dredging volumes, a maximum dredging depth of -40 ft-MLLW was assumed, as will be discussed in **Section 4**. As can be seen from the overfill factors and D_{50}'s the Willoughby Bank material appears to be a more compatible sand source then Thimble Shoal Channel.

Table 4. Overfill Factors for Willoughby Bank Borrow Area

Sample	Top Elevation of Sample (ft-MLLW)	D_{50} (mm)	Percent Fines (Passing #200 sieve)	Native Beach		Borrow Area		R_A
				$M_{\Phi n}$	$\sigma_{\Phi n}$	$M_{\Phi b}$	$\sigma_{\Phi b}$	
06OV-07 @ 0-0.5 FT	-23.7	0.36	5.7	1.36	0.89	1.38	1.32	1.21
06OV-07 @ 2-4 FT		0.34	4.1	1.36	0.89	1.57	1.03	1.24
06OV-07 @ 4-5 FT		0.15	18.6	1.36	0.89	ND	ND	ND
06OV-07 @ 7-8 FT		0.55	7.3	1.36	0.89	1.12	ND	ND
06OV-07 @ 13 FT		0.39	2.0	1.36	0.89	1.36	1.00	1.06
06OV-25 @ 0-0.5 FT	-13.6	ND	93.9	1.36	0.89	ND	ND	ND
06OV-25 @ 2-2.5 FT		0.58	12.8	1.36	0.89	1.18	ND	ND
06OV-25 @ 5-5.5 FT		0.72	4.5	1.36	0.89	0.45	1.09	1.00
06OV-25 @ 7 FT		0.51	10.7	1.36	0.89	0.99	ND	ND
06OV-25 @ 10-10.5 FT		0.82	1.3	1.36	0.89	0.29	0.74	1.00
06OV-25 @ 12 FT		0.59	0.9	1.36	0.89	0.55	ND	ND
06OV-25 @ 15 FT		0.62	0.6	1.36	0.89	0.63	0.71	1.00
06OV-25 @ 20 FT		0.50	8.7	1.36	0.89	0.99	ND	ND
06OV-27 @ 0-0.5 FT	-18.3	0.51	1.3	1.36	0.89	0.76	ND	ND
06OV-27 @ 2-2.5 FT		0.45	1.7	1.36	0.89	1.13	0.53	1.17
06OV-27 @ 5-5.5 FT		0.38	1.3	1.36	0.89	1.39	0.60	1.56
06OV-27 @ 10-10.5 FT		0.30	6.7	1.36	0.89	1.69	ND	ND
06OV-27 @ 15 FT		0.39	1.4	1.36	0.89	1.38	0.48	2.65
06OV-27 @ 19 FT		0.43	1.0	1.36	0.89	1.25	0.68	1.08
06OV-28 @ 0-0.5 FT	-15.4	0.47	1.2	1.36	0.89	1.06	0.75	1.00
06OV-28 @ 2-2.5 FT		0.49	0.6	1.36	0.89	1.01	0.54	1.04
06OV-28 @ 5-5.5 FT		0.13	28.9	1.36	0.89	ND	-0.76	ND
06OV-28 @ 10-10.5 FT		0.28	5.0	1.36	0.89	1.82	0.68	4.21
06OV-28 @ 18 FT		0.24	23.7	1.36	0.89	ND	ND	ND
06OV-30 @ 0-0.5 FT	-19.7 ft	0.22	15.1	1.36	0.89	ND	ND	ND
06OV-30 @ 2-2.5 FT		0.26	20.1	1.36	0.89	ND	ND	ND
06OV-30 @ 10-10.5 FT		0.23	11.2	1.36	0.89	2.25	ND	ND
06OV-31 @ 0-0.5 FT	-8.4	0.41	0.8	1.36	0.89	1.30	0.59	1.34
06OV-31 @ 2-2.5 FT		0.24	2.1	1.36	0.89	1.70	1.14	1.38
06OV-31 @ 5-5.5 FT		0.59	1.0	1.36	0.89	0.11	ND	ND
06OV-32 @ 0-0.5 FT	-21.5	0.41	3.1	1.36	0.89	1.27	0.81	1.00
06OV-32 @ 2-2.5 FT		0.17	17.5	1.36	0.89	ND	ND	ND
06OV-32 @ 5-5.5 FT		0.21	24.1	1.36	0.89	ND	ND	ND
06OV-32 @ 10-10.5 FT		0.26	4.0	1.36	0.89	1.92	0.56	ND
06OV-32 @ 16 FT		0.24	9.7	1.36	0.89	2.16	ND	ND
06OV-33 @ 0-0.5 FT	-14.1	0.45	1.7	1.36	0.89	1.11	0.78	1.00
06OV-33 @ 2-2.5 FT		0.34	2.8	1.36	0.89	1.66	0.84	1.64
06OV-33 @ 5-5.5 FT		0.27	6.9	1.36	0.89	2.11	ND	ND
06OV-33 @ 10-10.5 FT		0.09	32.5	1.36	0.89	ND	ND	ND
06OV-33 @ 16 FT		0.20	15.7	1.36	0.89	ND	ND	ND
06OV-35 @ 0-0.5 FT	-15.6	0.49	1.1	1.36	0.89	0.97	0.80	1.00
06OV-35 @ 2-2.5 FT		0.47	3.2	1.36	0.89	1.13	1.11	1.04
06OV-35 @ 5-5.5 FT		0.27	6.5	1.36	0.89	1.96	ND	ND
06OV-35 @ 10-10.5 FT		0.20	20.9	1.36	0.89	ND	ND	ND
06OV-35 @ 13 FT		0.20	25.2	1.36	0.89	ND	ND	ND
06OV-36 @ 0-0.5 FT	-23.3	0.28	3.6	1.36	0.89	1.74	0.93	1.66
06OV-36 @ 2-2.5 FT		0.41	6.0	1.36	0.89	0.92	ND	ND
06OV-36 @ 5-5.5 FT		0.49	2.6	1.36	0.89	0.99	0.78	1.00
06OV-36 @ 10-10.5 FT		0.49	1.3	1.36	0.89	0.97	0.63	ND
06OV-36 @ 15FT		0.48	0.5	1.36	0.89	1.01	0.76	1.00
06OV-37 @ 0-0.5 FT	-28.4	0.37	2.8	1.36	0.89	1.42	0.74	1.23
06OV-37 @ 2-2.5 FT		0.35	2.5	1.36	0.89	1.47	0.44	8.25
06OV-37 @ 5-5.5 FT		0.24	15.7	1.36	0.89	ND	ND	ND
06OV-37 @ 10-10.5 FT		0.21	33.9	1.36	0.89	ND	ND	ND
06OV-40 @ 0-0.5 FT	-27.4	0.32	2.0	1.36	0.89	1.58	0.71	1.80
06OV-40 @ 2-2.5 FT		0.33	7.0	1.36	0.89	1.54	ND	ND
06OV-40 @ 5-5.5 FT		0.21	35.4	1.36	0.89	ND	ND	ND
06OV-40 @ 10-10.5 FT		0.22	39.3	1.36	0.89	ND	ND	ND

3.2.3 *Other Possible Borrow Sources*

In 1990, the City of Hampton hydraulically dredged sand from Horseshoe Shoals and used this material to nourish Buckroe Beach. It has been shown to have a significant quantity of beach quality sand, however as will be discussed in **Section 7**, it is not recommended at this time due to its distance from Ocean View and subsequent higher dredging costs.

4 Permit Application Development

As mentioned, the City is seeking potential borrow areas for future beach nourishment projects along its Ocean View shoreline. In order to provide the City with optimal flexibility and long-term volume needs, a Joint Permit Application (JPA) was prepared for dredging, beach nourishment, and extension of existing stormwater outfalls along Ocean View. The draft Joint Permit Application, including associated permit drawings are included in **Appendix F**. Development of the permit application and drawings involved:

1. Calculation of available dredging volumes within each borrow area,
2. Determination of a beach fill template and volume, and
3. Determination of required outfall extensions.

4.1 Dredging Volumes

As discussed herein, two potential borrow areas, namely Thimble Shoal Channel, and Willoughby Bank were identified based on consideration of sediment compatibility and dredging costs. These areas are approximately 550 acres and 460 acres, respectively. Available dredging volumes were determined for each area using the Autodesk Land Development Desktop (LDD) software package. Included with the draft JPA in **Appendix F**, Figures 1-4 summarize the dredging volumes, borrow areas, and typical cross-sections.

For the Thimble Shoal borrow area, existing ground elevations were determined using the vibracore survey depths along with survey depths obtained in March 2005 following dredging of Thimble Shoal Channel for the Willoughby Spit to Central Ocean View project. In order to extend the existing ground surface to the borrow area boundary, depths indicated on NOAA Navigational Chart No. 12222 were used along the north, east, and west boundaries (e.g. where more accurate post-dredging surveys were unavailable). All elevations were converted to ft-MLLW. The maximum dredge depth was assumed to be the authorized channel depth of -55 ft-MLLW. It should be noted that actual dredge depths may exceed this depth by 2-3 feet due to over dredging. Based on the relative elevations, the total available volume of material was determined to be approximately 12.1 million cubic yards.

For the Willoughby Bank borrow area, existing ground elevations were determined using the vibracore survey depths. The existing ground surface was also extended to the borrow area boundary using nearby bathymetric survey data from McKim & Creed's recent survey of Ocean View Beach (March 2006) and depths indicated on NOAA Navigational Chart No. 12222. All elevations were converted to ft-MLLW. As stated, a maximum dredge depth of -40 ft-MLLW was assumed, based on the maximum depths of beach quality material indicated in the recent

vibracore samples. It should be noted that actual dredge depths may exceed this depth by 2-3 feet due to over dredging. The total available volume of material was determined to be approximately 13.1 million cubic yards within the Willoughby Bank borrow area.

4.2 Proposed Beach Fill Template

The JPA includes a proposed beach nourishment project covering approximately 7.2 miles of shoreline at Ocean View. The purpose of the project is to abate a chronic shoreline erosion problem, increase protection to public and private property, provide storm protection, and restore the public beach. As noted in the JPA, it is envisioned that the City will complete individual smaller beach nourishment projects over time, as needed. The permit, as submitted, would be valid for a six-year time period from 2006 to 2012.

Based on these requirements, a beach fill template including a sufficient dune and berm for storm protection was developed. The beach fill template was developed with consideration of previous dune and berm alignments designed for the East Ocean View and Willoughby Spit to Central Ocean View nourishment projects and to maximize storm protection, particularly in historically eroding areas. Detailed plan views and typical beach fill cross-sections are shown on Figures 5-19 of the draft JPA in **Appendix F**. In general, the proposed dune involved fill placement to +11 ft-NAVD88 with 1V:5H (vertical:horizontal) seaward and landward face slopes. The top width of the dune was set to 30 feet, except where the dune tied into an existing higher dune (e.g. no landward slope). The berm was designed to +5 ft-NAVD88 with a seaward slope of 1V:20H. The width of the berm varied alongshore and behind/between existing breakwaters from 25 ft to 215 ft, with an average width of 100 ft. As noted, beach fill was maximized in critical areas, including areas downdrift of existing breakwater fields.

Having developed the beach fill template, a required beach fill volume was determined by comparison of the proposed surface to an existing ground surface based on McKim & Creed's March 2006 survey of Ocean View. The total beach fill volume was determined to be 2.37 million cubic yards as shown on Figure 1 of the draft JPA in **Appendix F**. The overall average unit volume placement was computed as approximately 54 cubic yards per linear foot of beach (cy/ft). **Table 5** shows average unit volumes for various portions of the shoreline. Stations indicated in the table reference those shown on Figures 6 through16 in the draft JPA in **Appendix F**. It should be noted that the shoreline will likely continue to erode, particularly in critical areas. Therefore, actual unit volume placements may exceed those calculated for permitting purposes.

Table 5. Calculated Average Unit Volumes for Proposed Beach Nourishment

Region	Station Range	Unit Volume (cy/ft)
Willoughby Spit	0+00 – 48+00	53
800 Block Breakwater Field	48+00 – 94+00	50
West Ocean View	94+00 – 168+00	73
Central Ocean View Breakwater Field	168+00 – 203+00	65
Central Ocean View	203+00 – 325+00	62
West of East Ocean View Breakwater Field	325+00 – 346+00	80
East Ocean View Breakwater Field	346+00 – 381+00	54

4.3 Stormwater Outfall Extensions

Stormwater outfall extensions were also proposed in the JPA, to maintain functionality of the outfalls with the proposed nourishment project. The JPA includes extension of 12 stormwater outfalls at 10 locations (i.e. two locations include parallel pipes) as detailed in Figures 20 through 29 in the draft JPA in **Appendix F**. The required outfall extension lengths were determined by comparing existing outfalls to the proposed beach fill template and extending the outfalls until a minimum of approximately 2 feet of clearance was provided between proposed ground and the pipe invert. This resulted in outfall extensions ranging from 90-252 feet from the existing ends.

In the Fall and Winter of 2005, and early 2006 eleven outfalls were extended under two separate contracts. TJ Crooks extended 4 outfalls (Beaumont St., Grove Ave., 1st Bay St. and 27th Bay Street) for a bid price of $566,476. Earley Marine extended seven outfalls at five locations (1st View St., Ocean View Park, West of Pinewell, Elnora St. and Chesapeake St.) for a bid price of $599,333. For purposes of budgeting, an average cost to extend the outfalls under these two contracts was approximately $1,400 per linear foot of pipe.

5 Potential Permit Issues

Appendix G contains minutes from a January 12, 2006 meeting with regulatory agencies who will be involved in the review of the City's permit for dredging and beach nourishment. The meeting was to determine if there were any areas being considered for borrow that should be avoided. The agencies encouraged the City apply for a single permit to include the borrow areas and beach fill, and did not rule out any area being considered. The minutes document other issues raised.

Another recommendation from the agencies was to review the permit from the Buckroe Beach nourishment project to see what requirements were listed for Horseshoe Shoals borrow area. It was thought that permit issues at Horseshoe Shoals would be similar to those encountered at Willoughby Bank and Thimble Shoal Channel. Based on the previous permit obtained in 2004 by the City of Hampton to hydraulically dredge sand from Horseshoe Shoals and pump and deposit it along the shoreline at Buckroe Beach, the following issues may be of concern to this project:

- The corners of the borrow area shall be marked with USCG approved lighted buoys.
- The route of pipeline shall be marked with 50-inch circumference buoys spaced at 500-foot intervals.
- All materials shall be pumped through a submerged pipeline laid on the bottom.
- The pipeline shall be placed in a position directly from the designated small boat channel along the marked route.
- A post-dredge bathymetric survey of the borrow area shall be submitted within 30 days of completion of the dredging.
- The Permittee shall not dredge from July 1 through September 15 in order to protect migrating and spawning blue crabs.

- The Permittee shall not dredge either the side slopes surrounding the existing borrow pit areas or within the existing borrow pit areas from December 1 through March 31 to protect the winter buried crabs and to allow unimpeded access to the borrow pit areas by crab dredgers during the crab dredge season.

The Virginia Institute of Marine Science (VIMS) also had concerns about the Buckroe Beach project. The placement of material along the shoreline and the mining of the material will cause elevated turbidity levels. Given the circulation patterns in the Hampton Roads area, the increased turbidity should be relatively short-lived. Both the nourishment and the dredging activities will have an impact on the benthic community. After the completion of the dredging, the appropriate species should repopulate the area fairly quickly. Special care must also be taken to prevent injury to the endangered sea turtles that are in the area from late May through the fall. They spend a considerable amount of their time feeding on the bottom and could therefore be harmed by a dredge. Special care should also be taken to avoid any public oyster grounds.

The Department of Conservation and Recreation (DCR) will search its Biological and Conservation Data System (BCD) for occurrences of natural heritage resources in the proposed project areas. Natural heritage resources are defined as the habitat of rare, threatened, or endangered plant and animal species, unique or exemplary natural communities, and significant geologic formations. If any of the project areas are located in a conservation site, DCR will implement restrictions as necessary.

The Department of Historic Resources (DHR) addressed their concerns as well. They advise that the borrow areas be surveyed to determine if they are historical sites, such as those containing historical shipwrecks. If so, they need to be further investigated or avoided. The DHR also recommends that the Permittee consider the potential of the constructed berms to affect historic buildings and structures.

For previous projects using material from Thimble Shoal Channel, the National Marine Fisheries Service (NMFS) imposed the following restrictions regarding sea turtles. If dredging occurs between April 1 and November 30, hopper dredges must be equipped with the rigid deflector draghead or a rigid sea turtle deflector attached to the draghead. NMFS-approved observers must be present on hopper dredges once surface waters reach or exceed 11° C, or during the period of April 1 through November 30 (whichever occurs first) of any year to monitor hopper spoil, overflow, screening and dragheads for sea turtles and shortnose sturgeon and their remains.

6 Additional Work Required

Based on the background search for the Buckroe Beach project, it is expected that a magnetometer survey will be required by the agencies to determine the existence of unexploded ordnances (UXO) in the Willoughby Bank area. No information was available from the Corps of Engineers to determine if UXOs would be an issue. If found, screening for UXOs, at the hopper or cutterhead, would be required. At Horseshoe Shoals, UXO's were present and screening at the cutterhead was required. This only slightly increased the cost of dredging by $110,000 or $0.40 per cubic yard. Two companies were contacted to get an idea of the costs associated with

a magnetometer survey. Mid-Atlantic Technology and Environmental Research, Inc. provided an estimate for a magnetic and side-scan sonar survey of the Willoughby Bank area to be around $17,000. The survey would be on a 20-foot line spacing adding up to above 240 nautical line miles. Tidewater Atlantic Research performed the survey at Horseshoe Shoals in 2003. The survey covered an area of approximately 360 acres. The cost of the survey, data analysis and report was $34,745.00 in 2003. That comes to approximately $100 per acre, or $46,000 for 460 acres. The range in prices is likely high due to the project not being scoped in detail with Mid-Atlantic. Actual costs, with inflation, would likely be closer to $60,000.

From a meeting on January 19, 2006, VMRC stated that the Willoughby Bank area has known clam beds and mitigation would be required. The replacement ratio was suggested to be 1 ⅓ clams mitigated for every 1 clam removed. VMRC quoted this mitigation cost to be about $0.17 to $0.20 per clam. According to VMRC, the Willoughby and Crumps Bank area has been shown to have approximately 4 clams per square meter. The agencies may require a survey to determine clam density within the proposed borrow areas. To get an idea of the cost impact should clams have to be mitigated for, assume 25% of the Willoughby area is used for a project. In say, 130 acres, there would be 16,000+/- clams. At $0.20/clam this would be $560,000 in potential clam mitigation. In all the vibracores taken in the Willoughby Bank area, no clams were noted. According to VMRC any required study to determine the density of clams would be completed by the agencies. It appears no clam mitigation was required at Horseshoe Shoals.

Detailed hydrographic surveys would be completed, at the time of the above work, to complement the data collected. The information would also then be available for the preparation of plans and specifications. Hydrographic surveys of each area are estimated to be approximately $7,000 for each site.

7 Dredging Costs

To better evaluate each of the proposed borrow areas, a budget level opinion of probable cost was performed. The opinion of probable cost evaluates beach nourishment dredging costs for using Thimble Shoal Channel (TSC), Willoughby Bank, and Horseshoe Shoals, using both hopper dredge and hydraulic cutter-head pipeline dredge.

Available historic project information was used to assist in preparing these costs. TSC has been used for two recent City of Norfolk beach nourishment projects. During November and December of 2003 Weeks Marine placed 359,000 CY from TSC for $2,559,274, along East Ocean View, or $7.12/CY. This work was contracted through a modification to an ongoing Corps of Engineers (COE) maintenance dredge contract. Please note that the above contract amount reflects the COE paying the cost of the hopper dredge mobilization and demobilization. The most recent City project was with Great Lakes Dredge and Dock (GLDD), who used TSC for the Central Ocean View nourishment project. From December 2004 through March 2005, GLDD placed approximately 428,000 CY for $9/CY. Both contractors used hopper dredges.

In late 2004 through early 2005, GLDD used a cutter head dredge to nourish Buckroe Beach. The COE contract[1] was to place 281,000 CY of sand from the Horseshoe borrow area along Buckroe Beach. The bid price was $6.80/CY, $992,000 for mob/demob, and an additional $110,000 to deal with screening the borrow material for unexploded ordinance. A separate unit price bid item of $7.20/CY was for placing 100,000 CY along Salt Ponds.

No known dredging projects have used the proposed Willoughby and Crumps Bank material for borrow.

Table 6 is a summary of the cost analysis based on the City's proposed first nourishment contract of about 400,000 CY along East Ocean View. The table summarizes the probable lowest cost method for each area, taking into account dredge distance, and draft restriction at each proposed site. Any additional required costs, such as for clam or crab mitigation, screening required if UXO are present, or requirements to dredge during turtle migration season are not included.

Table 6. Summary of Borrow Source Cost Analysis

	Willoughby Bank	Thimble Shoal Channel	Horseshoe
Type of Dredge	Hopper (3,500 CY)	Hopper (3,500 CY)	Hopper (3,500 CY)
Assumed Volume for Beach Fill	400,000 CY	400,000 CY	400,000 CY
Mob/Demob	$1,000,000	$1,000,000	$2,250,000
$/CY Beach Fill	$8.20	$9.10	$11.70
Total	**$4,280,000**	**$4,640,000**	**$6,930,000**
Est. Time	11 weeks	12 weeks	13 weeks

8 Summary & Recommendations

Based on the findings of this study and input from the City and regulatory agencies, it is recommended to apply for a permit to use Willoughby and Thimble Shoal Channel as borrow sources for future beach nourishment projects. The draft Joint Permit Application (JPA) is included in **Appendix F**. As can be seen from the overfill factors and D_{50}'s the Willoughby Bank material appears to be a more compatible sand source then Thimble Shoal Channel; however, having a permit to use either site provides greater flexibility for borrow source locations. Some cost savings can be realized by using a contractor who may already be doing maintenance dredging for the Corps of Engineers in the adjacent Thimble Shoals navigation channel. Willoughby Bank material can also be dredged with a pipeline cutterhead dredge. The cutterhead would be economical for beach projects closer to the west end of Ocean View where the required pipeline lengths are smaller.

It will most likely be required to respect time of year restrictions which may not allow dredging from July 1 through September 15 in order to protect migrating and spawning blue crabs in Willoughby and Crumps Bank (as was a permit restriction for the Buckroe Beach project).

[1] Information from Buckroe Beach Nourishment Project bid opening, dated September 15, 2004, COE Invitation Number W91236-04-R-0046.

During this time, it may be possible to dredge Thimble Shoal Channel as long as NMFS restrictions are followed to protect the safety of sea turtles in the area. The Department of Historic Resources will need to be contacted to determine if any of the borrow areas are historical sites. Additionally, the Department of Conservation and Recreation will review the permit to determine if there are natural heritage resources in the proposed project areas.

During review of the JPA, the regulatory agencies may ask for magnetometer, hydrographic and/or clam density surveys. If requested, it is estimated the magnetometer survey will cost $60,000 and the hydrographic surveys will cost $7,000 per borrow area site. Clam density surveys will apparently be at the expense of the regulatory agencies. Additional projects costs could also occur from the mitigation of clams. At worst case, this mitigation cost may approach $560,000, based on information provided by the agencies.

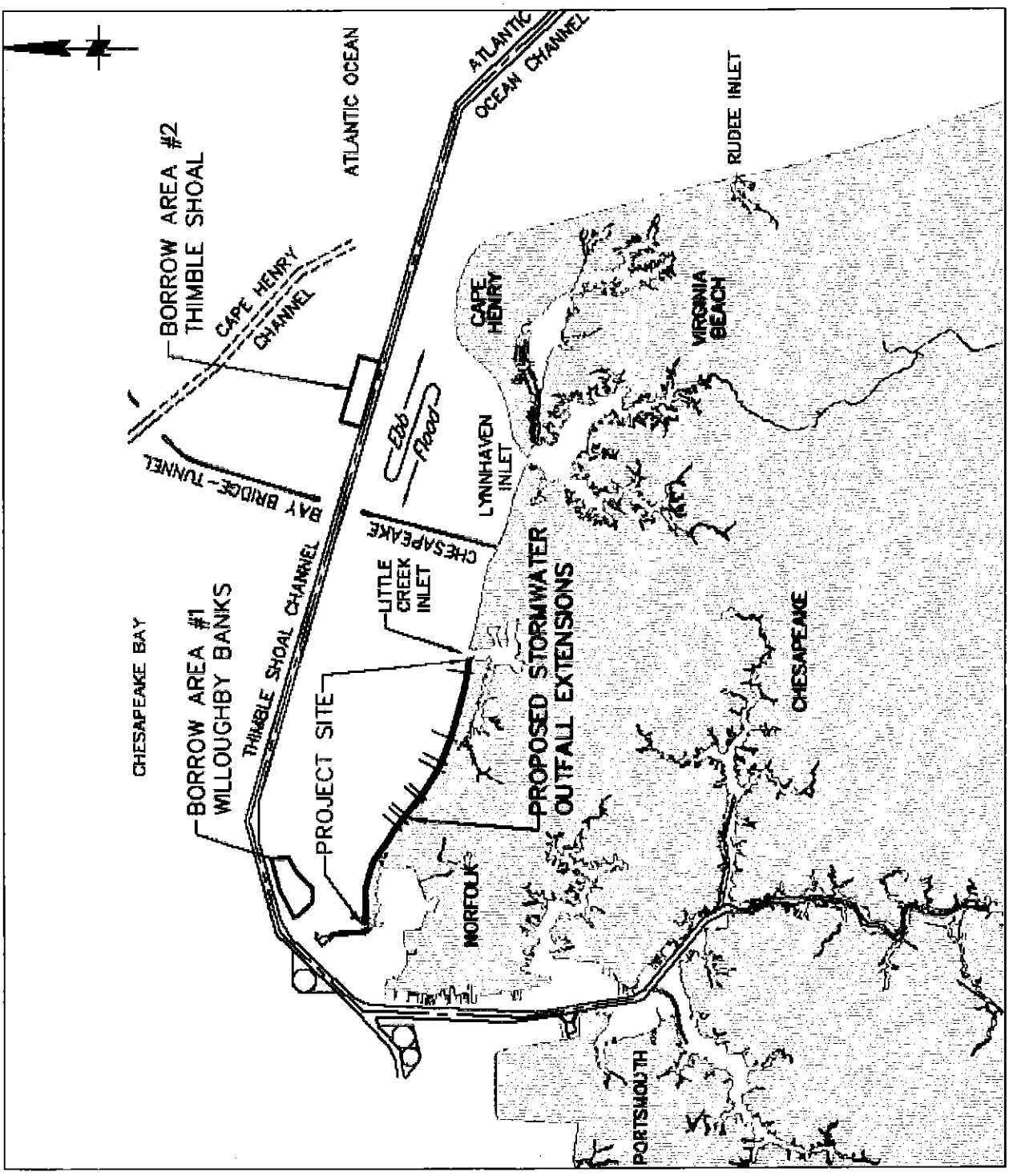


Figure 1. Overall Proposed Dredging and Beach Nourishment Project Plans

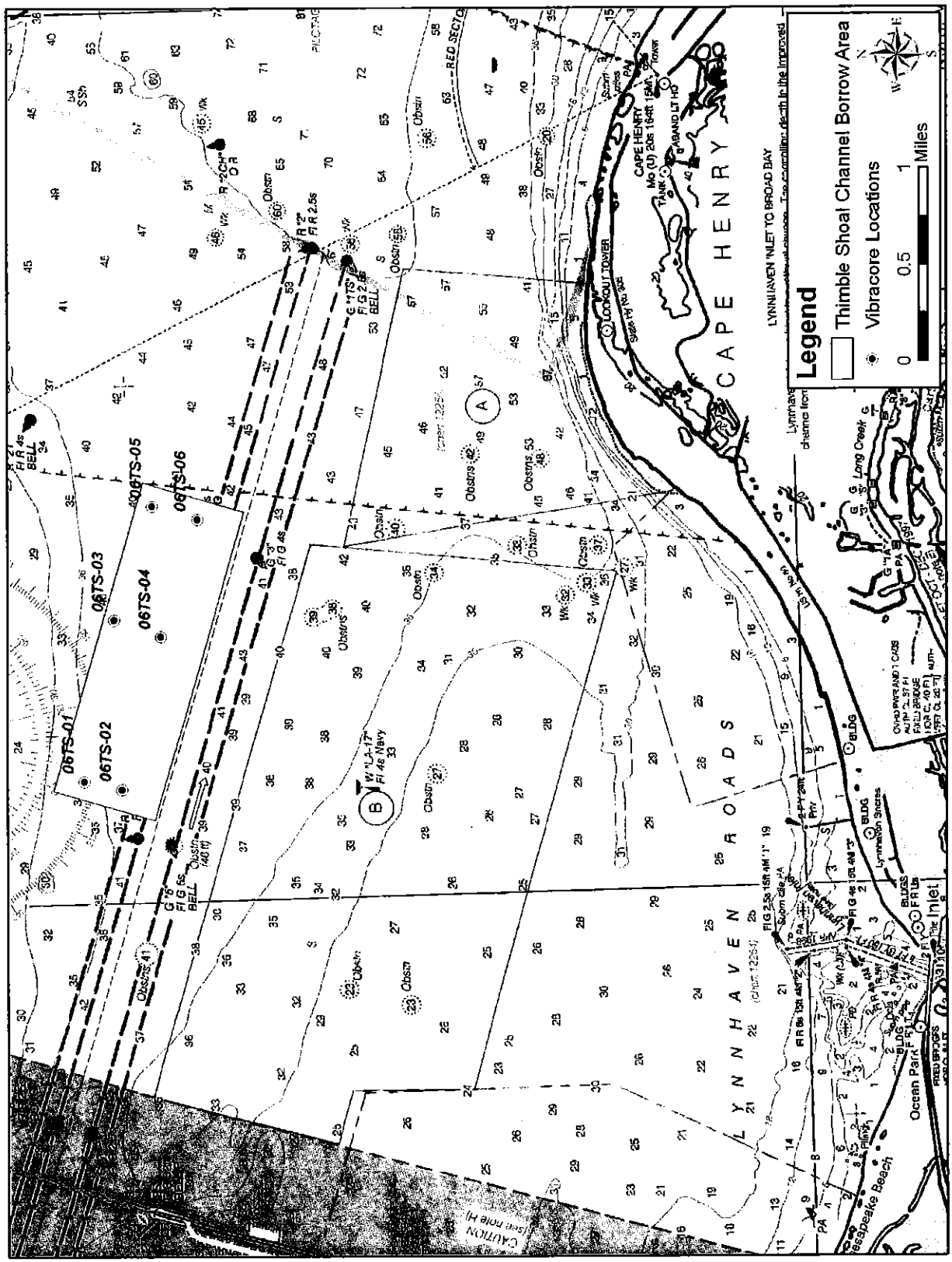


Figure 2. Locations of Vibracores – Thimble Shoal Channel

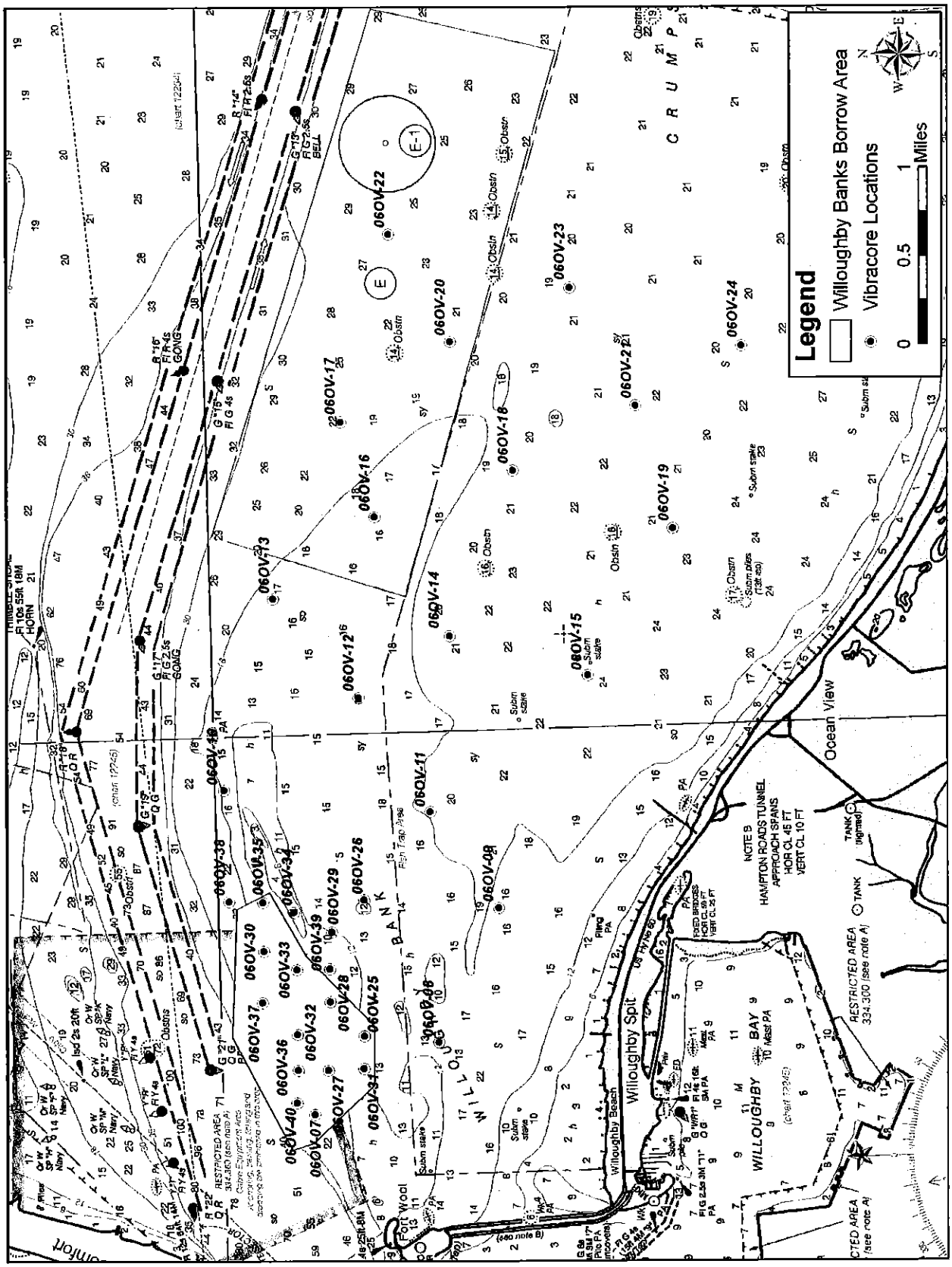


Figure 3. Locations of Vibracores – Willoughby & Crumps Bank

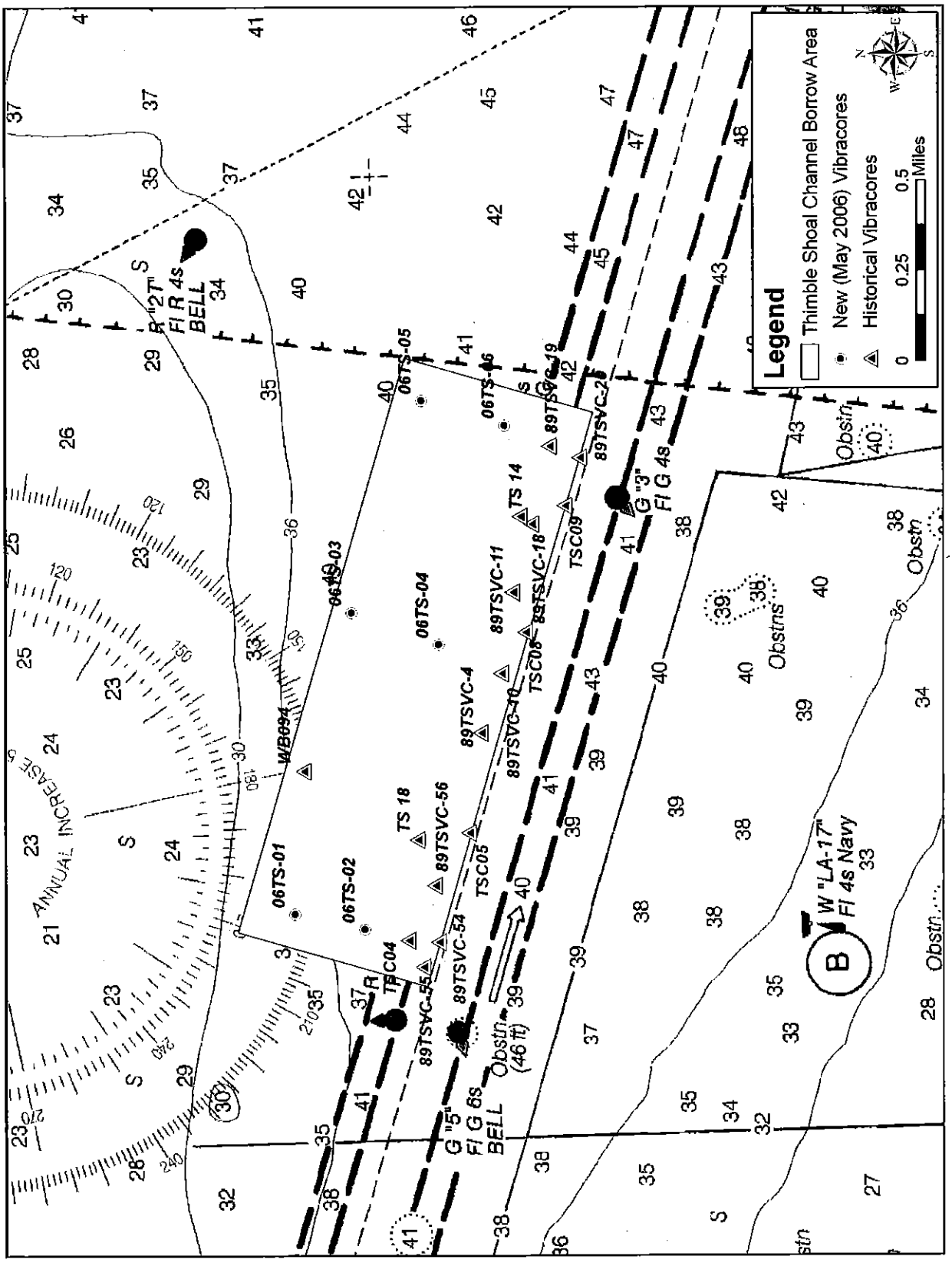


Figure 4. Thimble Shoal Borrow Area with New and Historical Vibracore Locations

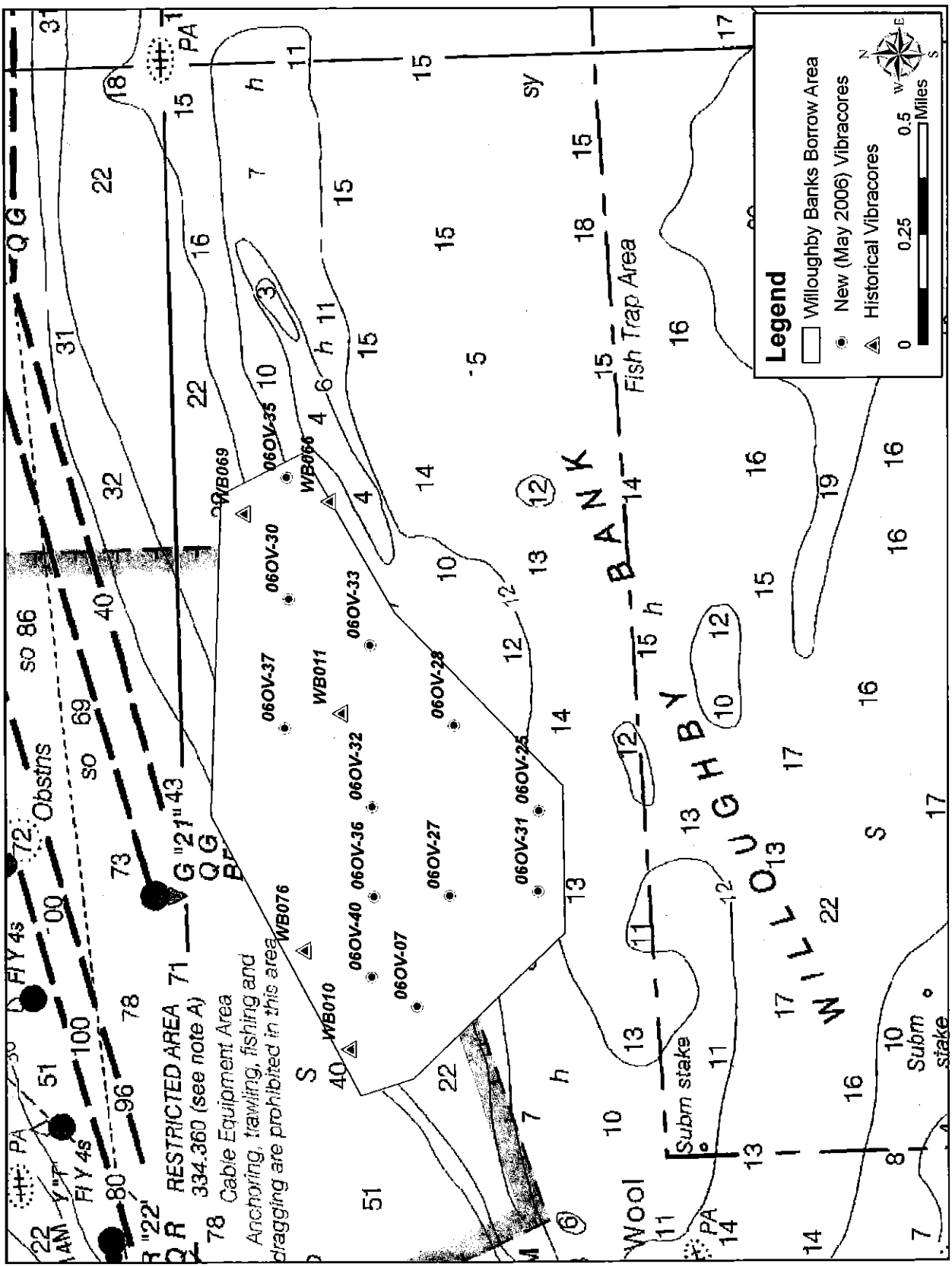
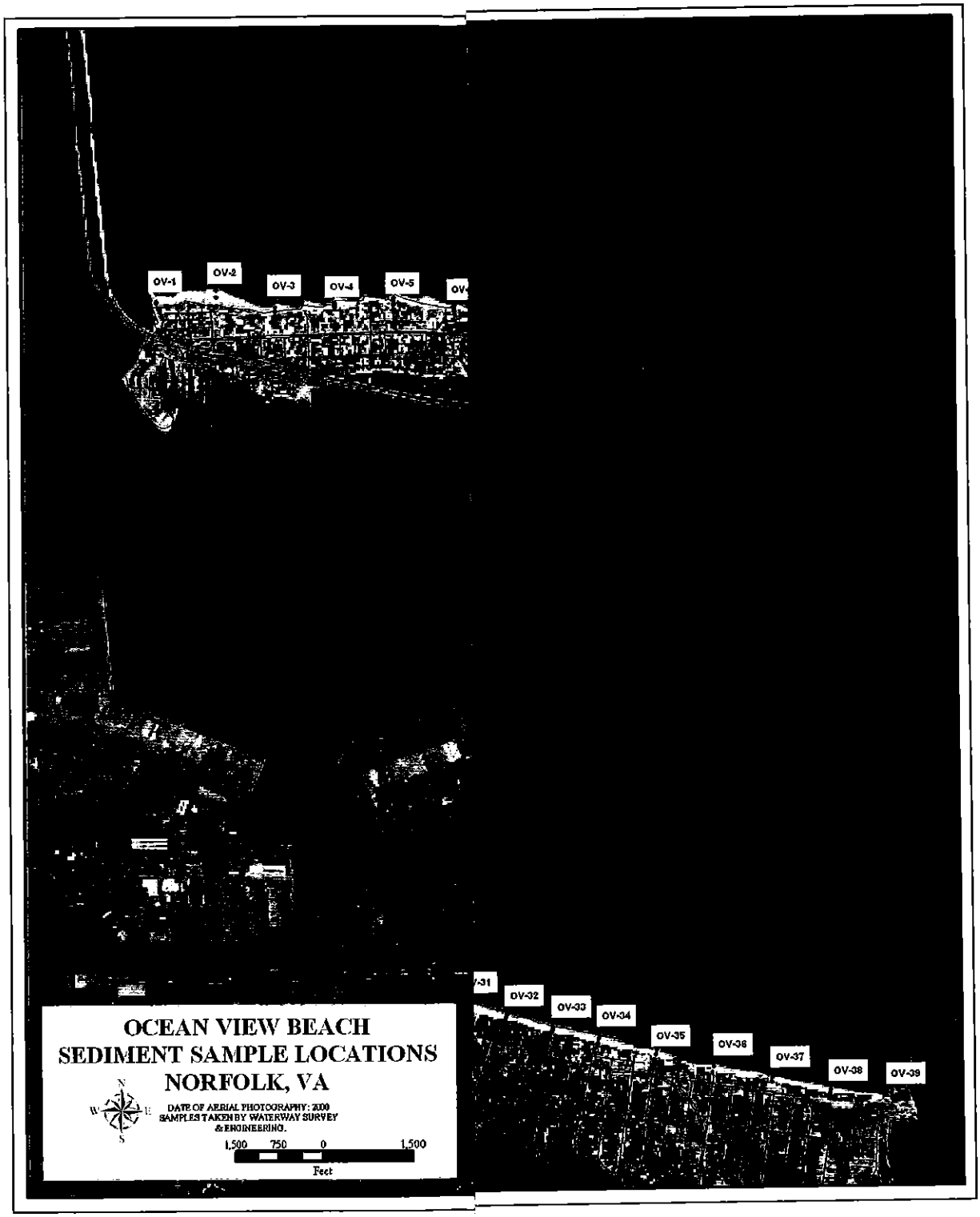


Figure 5. Willoughby Bank Borrow Area with New and Historical Vibracore Locations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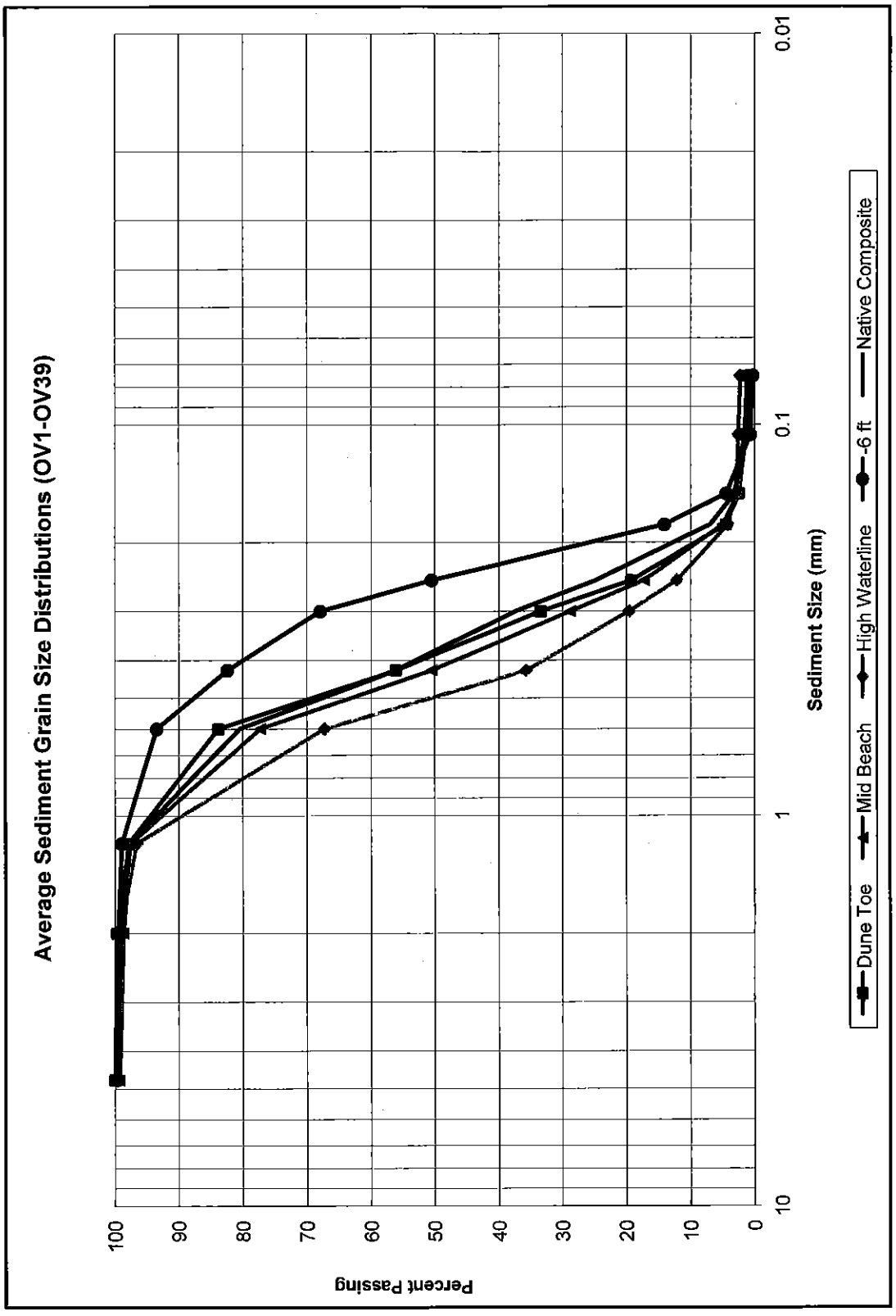

Figure 7. Average Sediment Grain Size Distributions and Resulting Composite Distribution for Willoughby Spit to East Ocean View

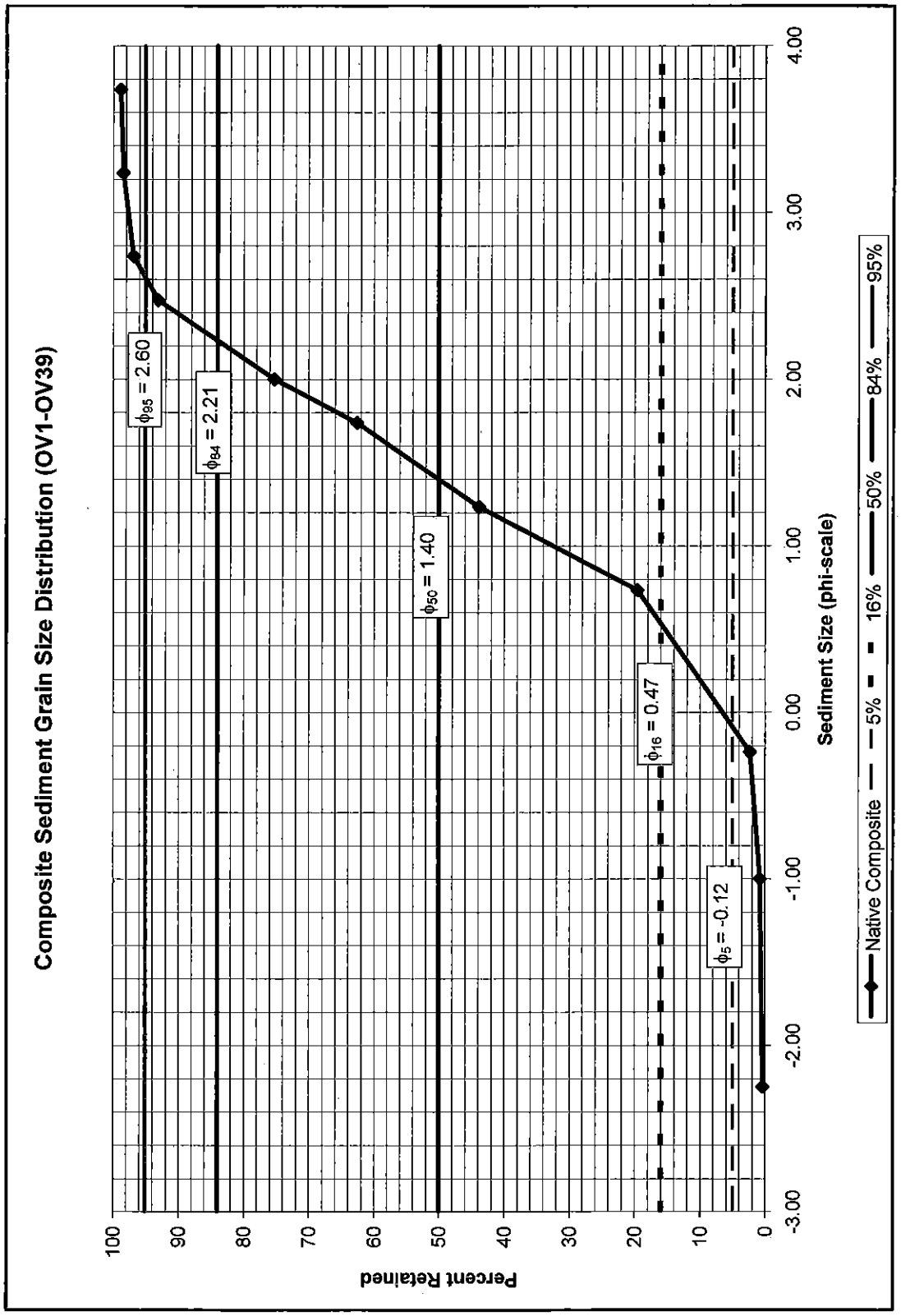

Figure 8. Phi-Scale Composite Grain Size Distribution for Native Material along Willoughby Spit to East Ocean View Based on Grab Samples